CMB polarisation from clusters and filaments

Guo Chin Liu

Antonio da Silva

Nabila Aghanim

Secondary CMB Polarisation

- Lensing effect

  Mode mixing

  due to E converted to B — e.g.:Zaldarriaga, Seljak, 1998

  Benabed et al. 2001

- Faraday rotataion

  phase shift

  → mode mixing — e.g.:Takada, Ohno, Sugiyama 2001

- Scattering off ionised gas

  power generated — Sunyaev, Zel'dovich 1980

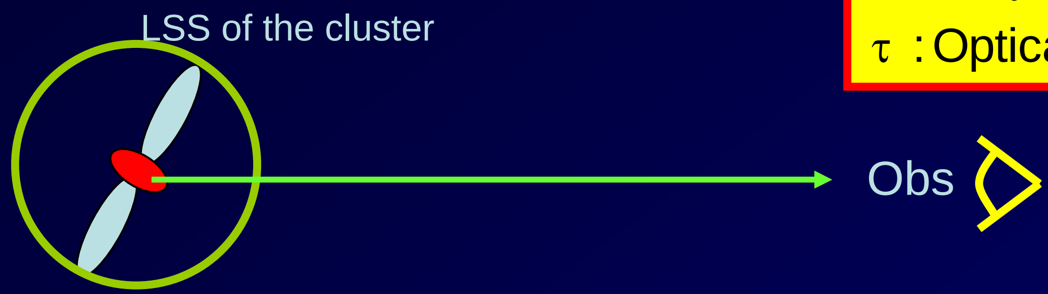
  e.g.:Sazonov, Sunyaev 1999

Sources of Quadrupole

1.Primordial CMB Quadrupole

$P \propto \tau Q_{cmb}$

τ : Optical depth



2. Kinetic Quadrupole

$P \propto \tau v_t^2$

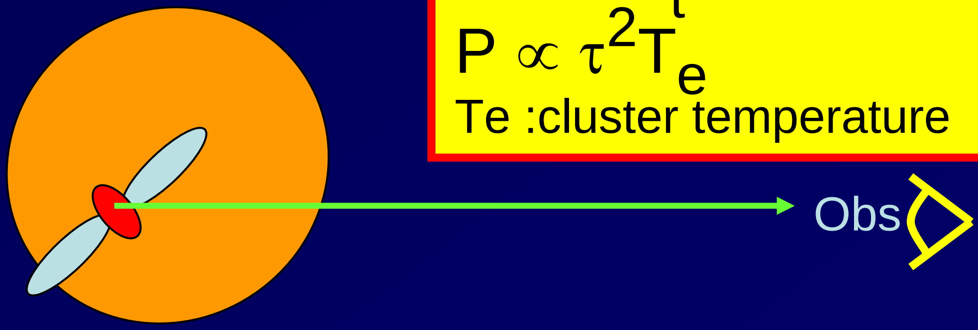
V_t : transverse velocity

3.Double scattering

$P \propto \tau^2 v_t$

$P \propto \tau^2 T_e$

Te :cluster temperature



Modulated Quadrupole

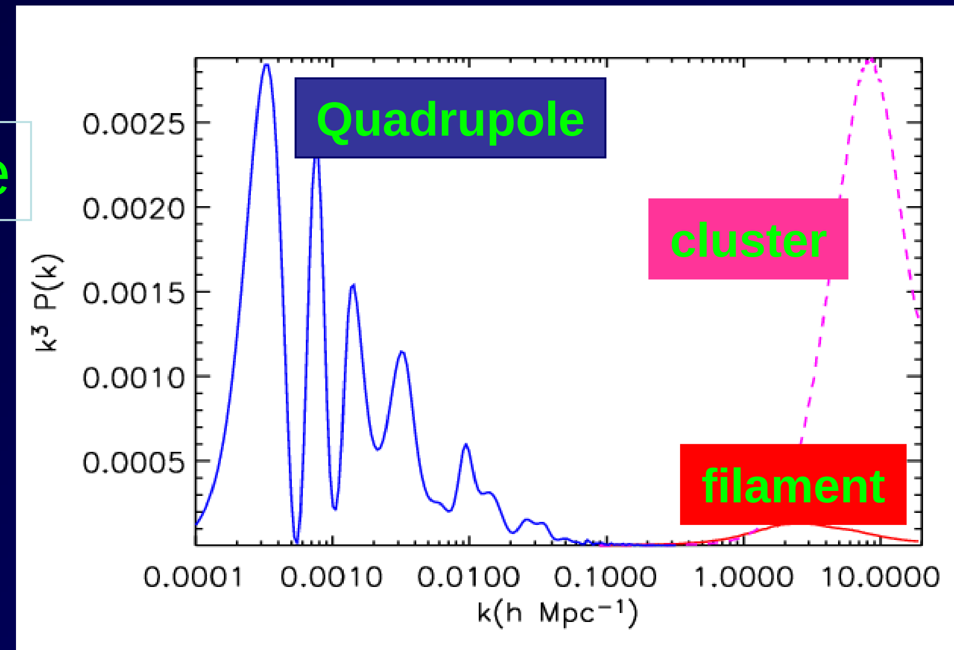
Density fluctuation | Quadrupole

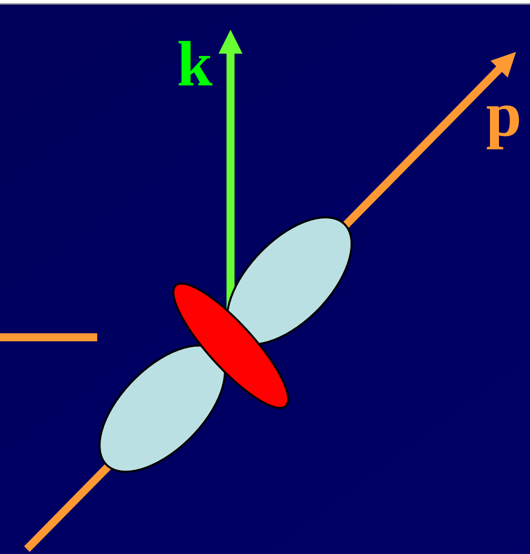
$S^m(\mathbf{k},\eta)$:

$$= \int d^3\mathbf{p}\ \delta_e(\mathbf{k}-\mathbf{p},\eta)\,\Box^m_{T2}(\mathbf{p},\eta)$$

$$\cong \delta_e(\mathbf{k},\eta)\int d^3\mathbf{p}\,\Box^m_{T2}(\mathbf{p},\eta)$$

$$=\delta_e(\mathbf{k},\eta)\int d^3\mathbf{p}\,\Box^0_{T2}(\mathbf{p},\eta)\,Y^m{}_2(\mathrm{p})$$





Formula

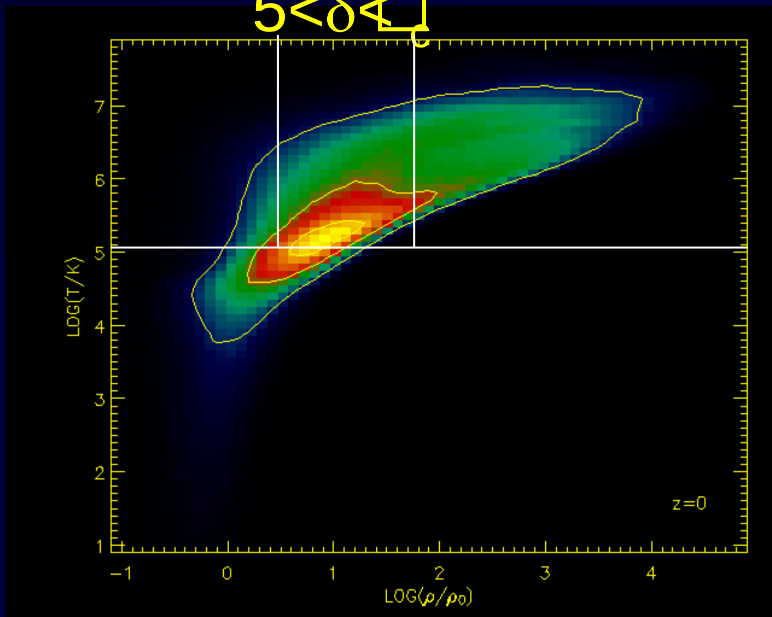
$g(\eta) \equiv - e^{\tau(\eta 0)-\tau(\eta)} \, d\tau/d\eta$

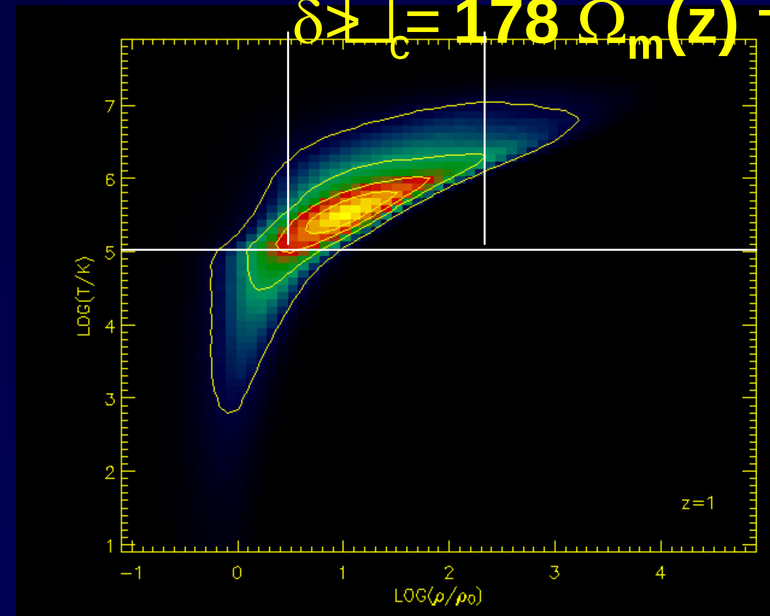
visibility function: possibility of last scattering at epoch η

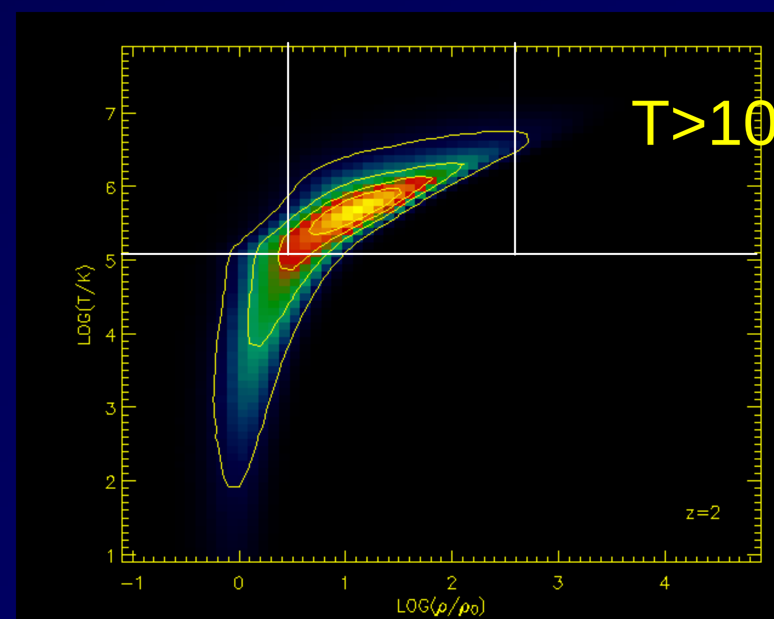
$$C_{(E,B)\ell} \propto \ell^4 \sum_m \int k^2 dk < | \int d\eta \, g(\eta) S^m(k,\eta) T^m_{(E,B)\ell}(k,r) |^2 >$$

m	T^m_{El}	T^m_{Bl}
0	$(-i)^l \, j_l(kr)/(kr)^2$	0
±1	$\pm (-i)^l \, [(l+1)j_{l-1}(kr) - l j_l(kr)] \, / \, [(2l+1)kr - \sqrt{6l(l+1)}]$	$\pm(-i)^l [\sqrt{3/2l(l+1)}]^* \, j_l(kr)/(kr)^2$
±2	$\pm(-i)^l \{[(l+2)(l+1)/(2l-1)+l(l+1)/(2l+3) -(2l+1)(l-1)(l+2)/(2l-1)(2l+3)] \, j_l(kr) -(l+2)(l+1) \, j_{l-1}(kr)/kr - l(l-1) \, j_{l+1}(kr)/kr\} \sqrt{(l-2)!/6(l+2)!)/(2l+1)}$	$\pm(-i)^l \{(l+2) \, j_{l-1}(kr) - (l-1) \, j_{l+1}(kr) \sqrt{(l-2)!/6(l+2)!)/(2l+1)}$

Gas Evolution







Ω_m=0.3

Ω_b=0.044

Ω_Λ=0.7

h=0.71

L_{box}=100h^{-1}Mpc

σ_8=0.9

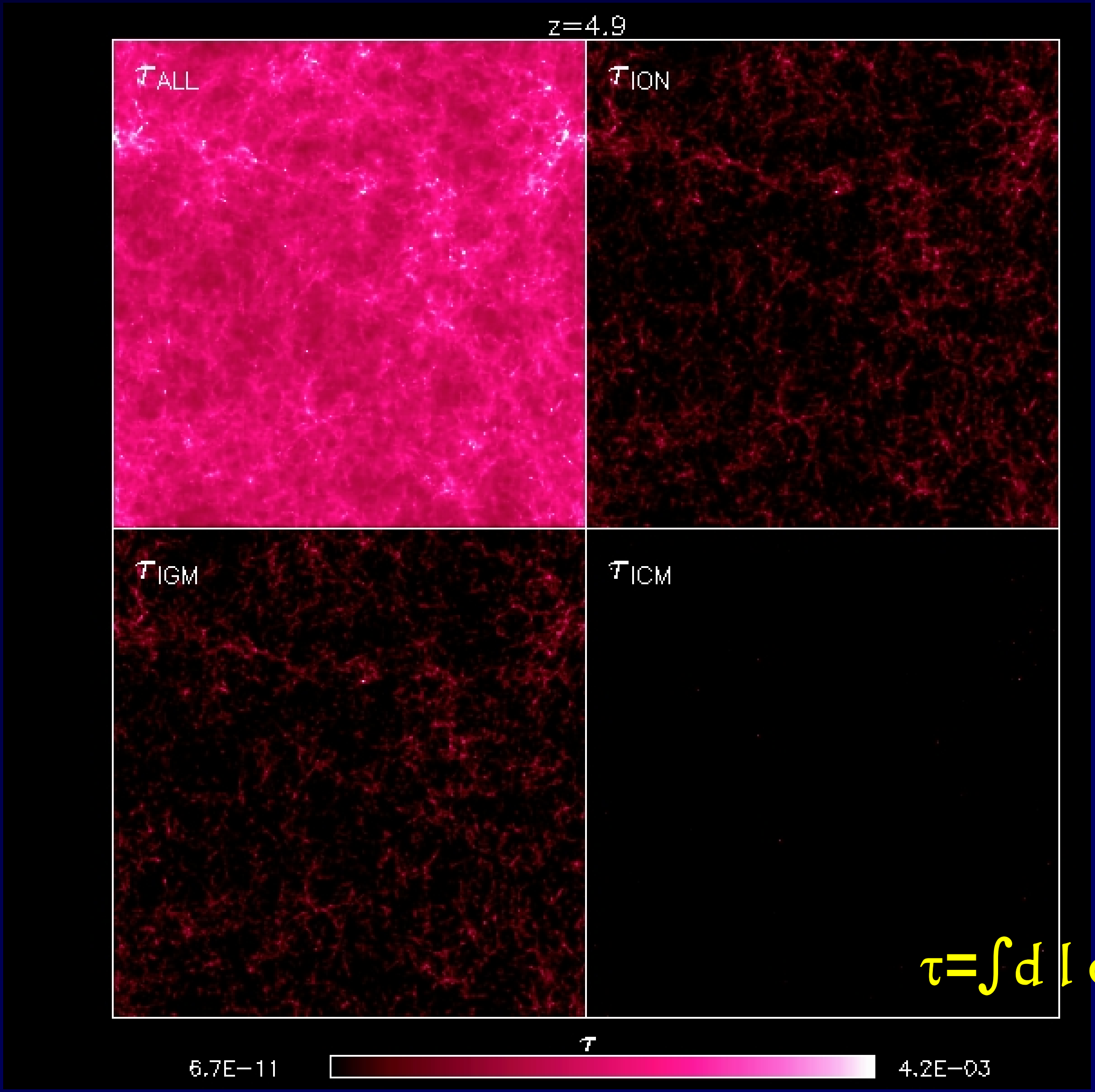
Mass of particle: 10^{10} M_o/h

Non-rad. Hydra Code

Couchnman et al. 1995

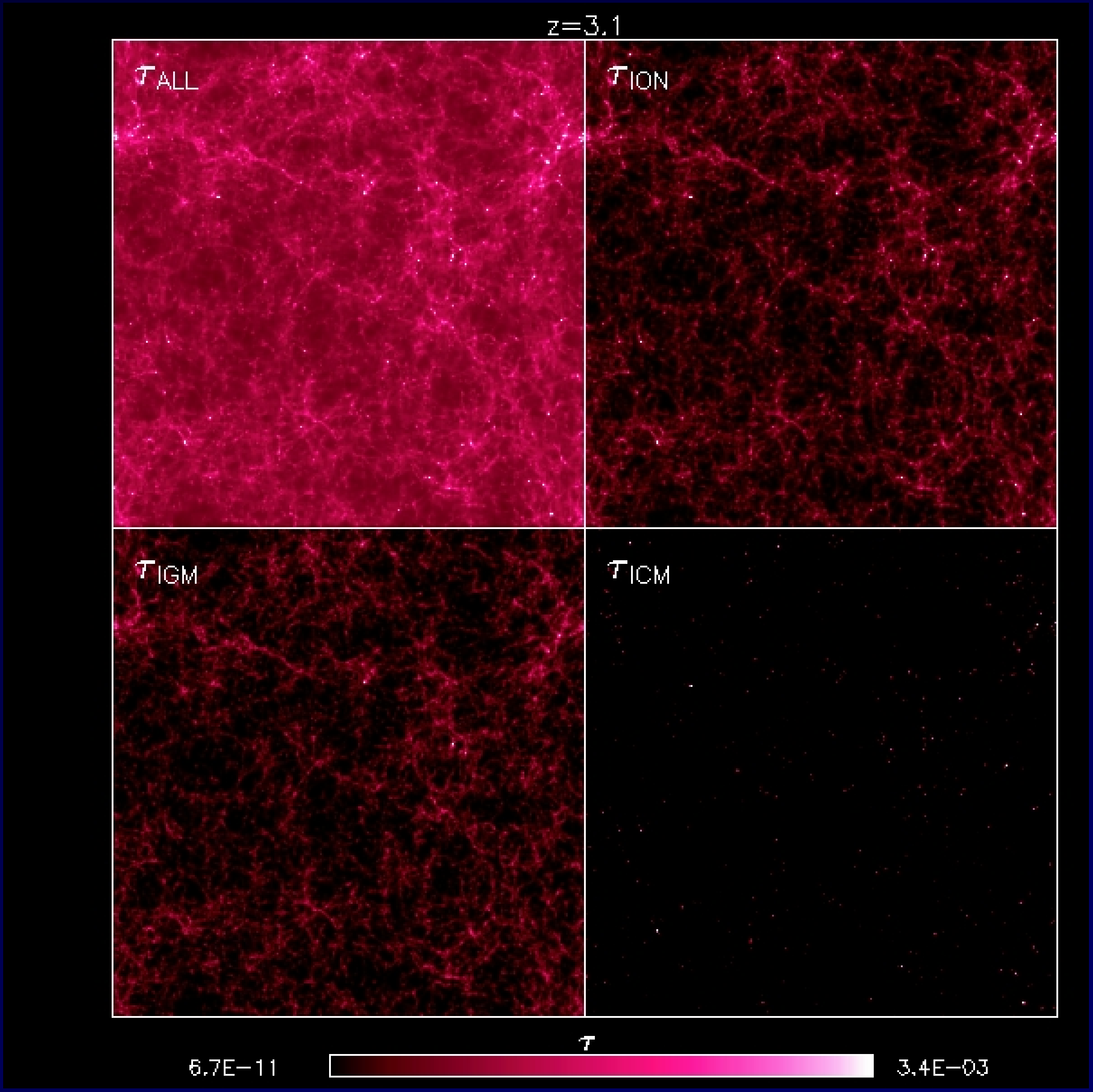
Pearce & Couchnman 1997

Gas Phase

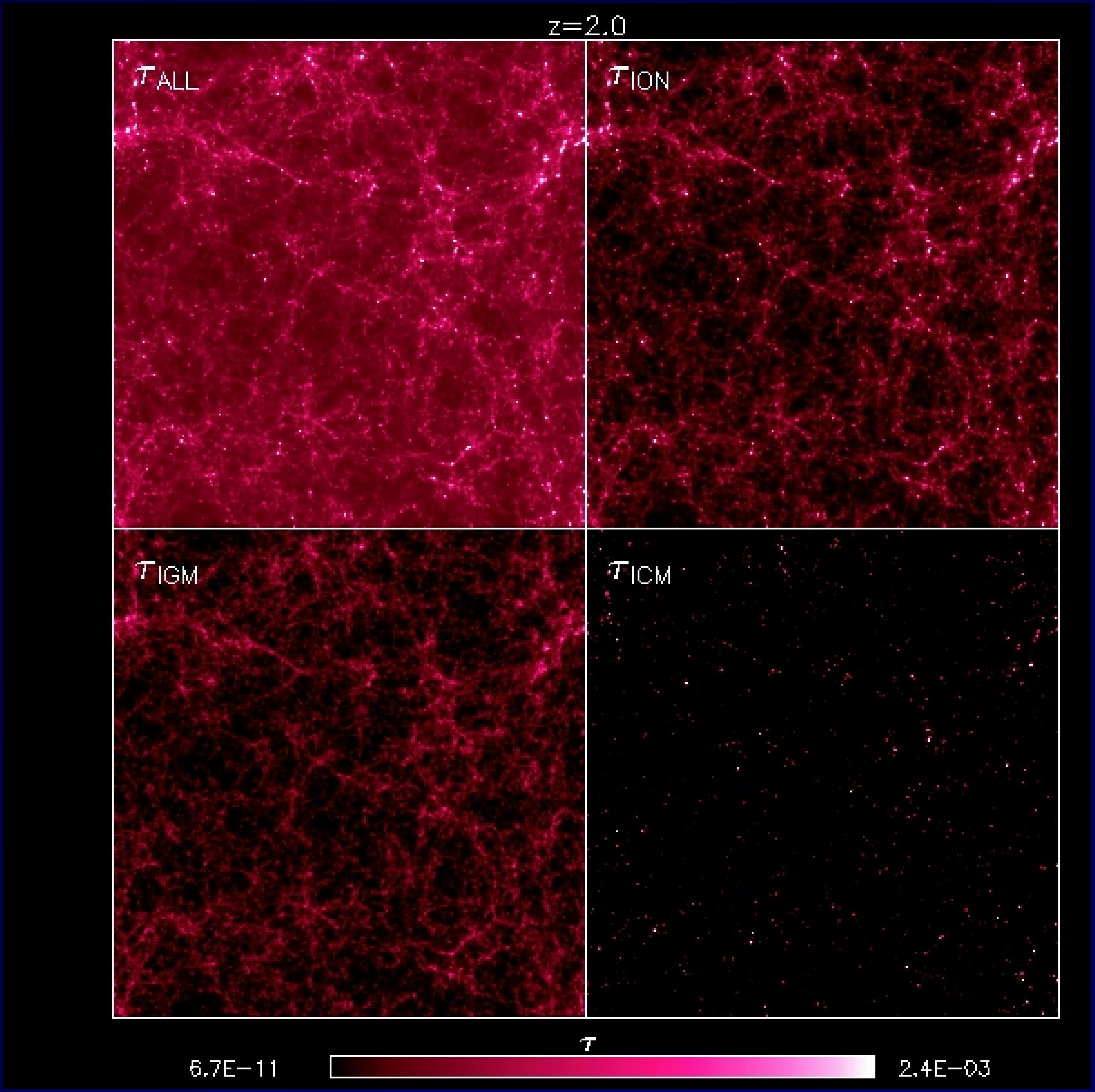


$\tau = \int dl\, \sigma_T\, n_e(\text{phase})$

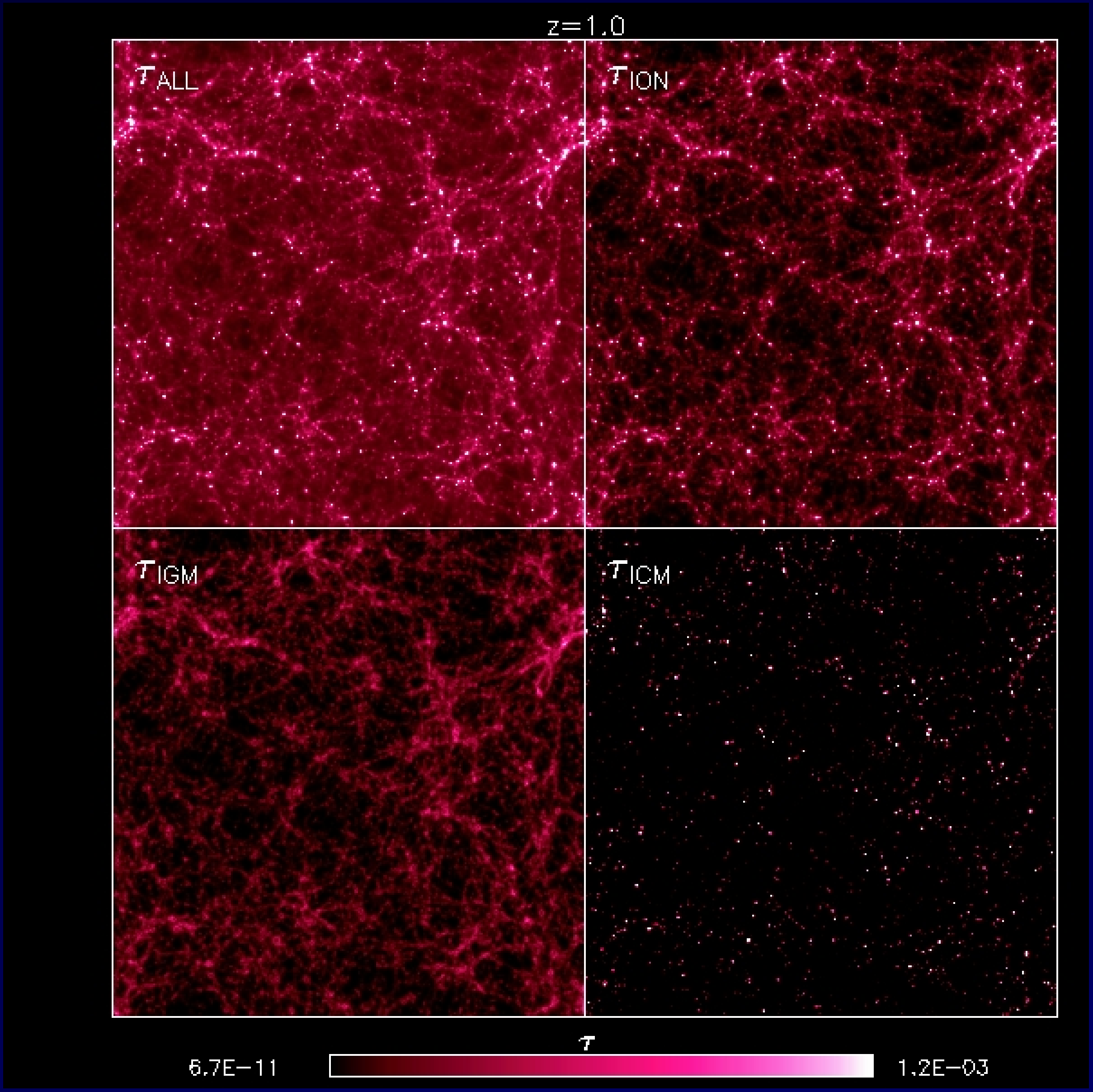
Gas Phase



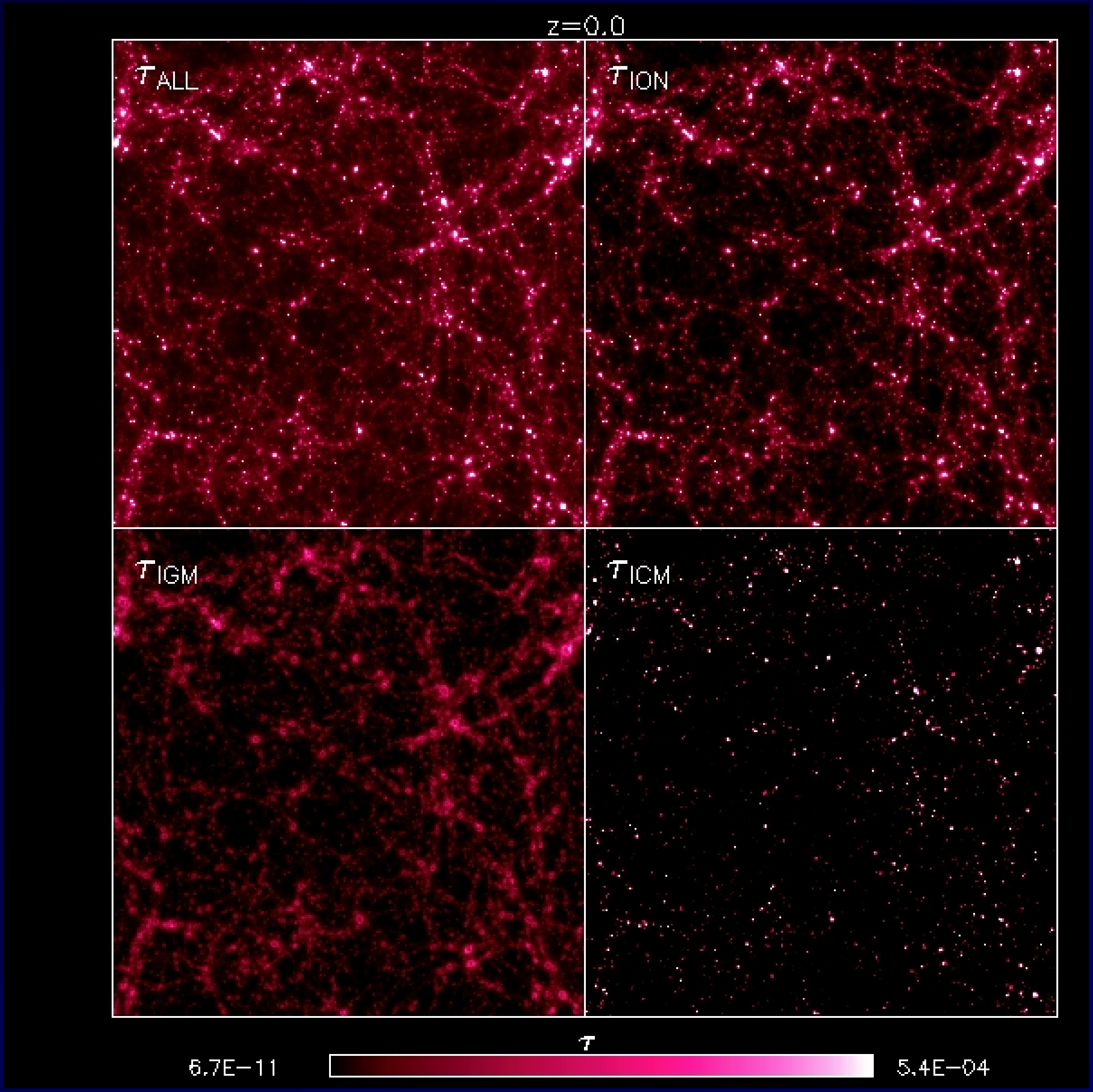
Gas Phase



Gas Phase

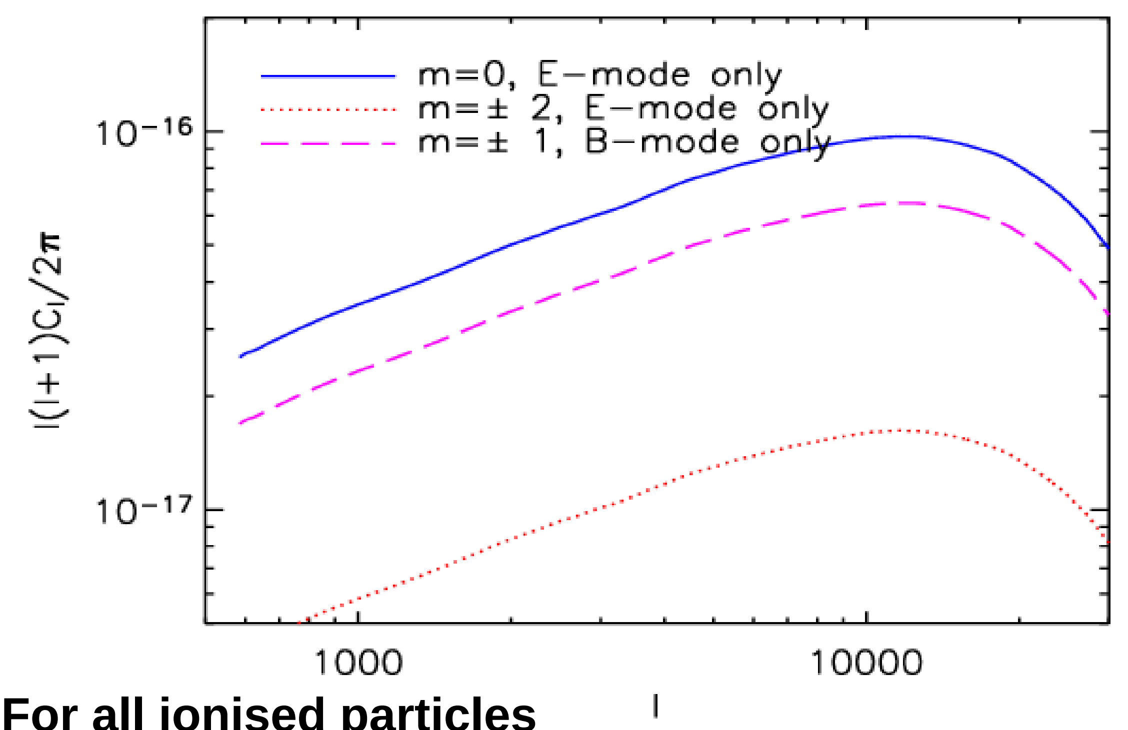


Gas Phase



E=B

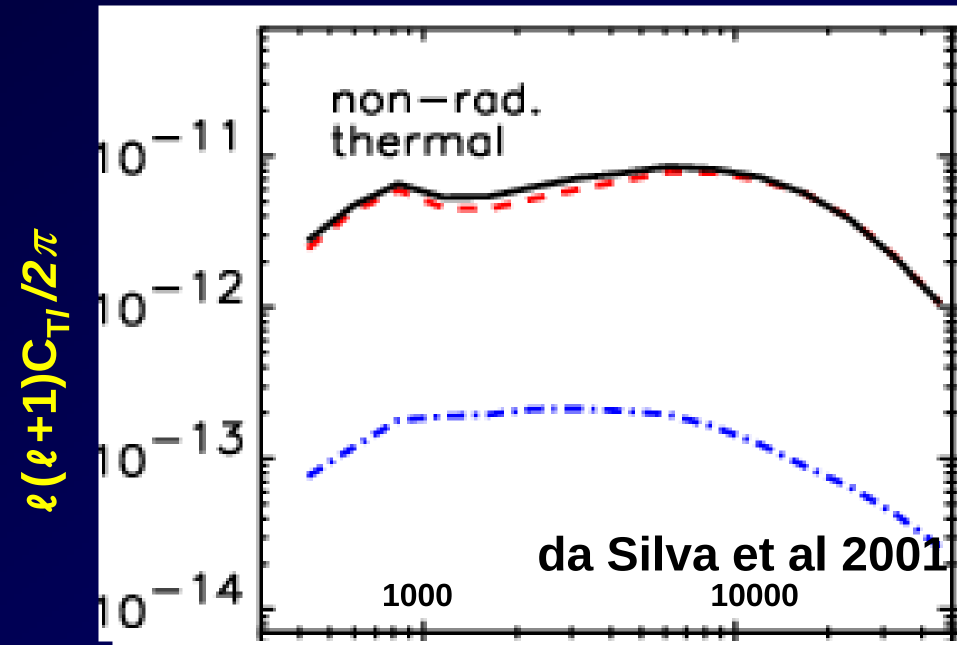
	E-mode	B-mode
m=0	6	0
m=±1	0	4
m=±2	1	0



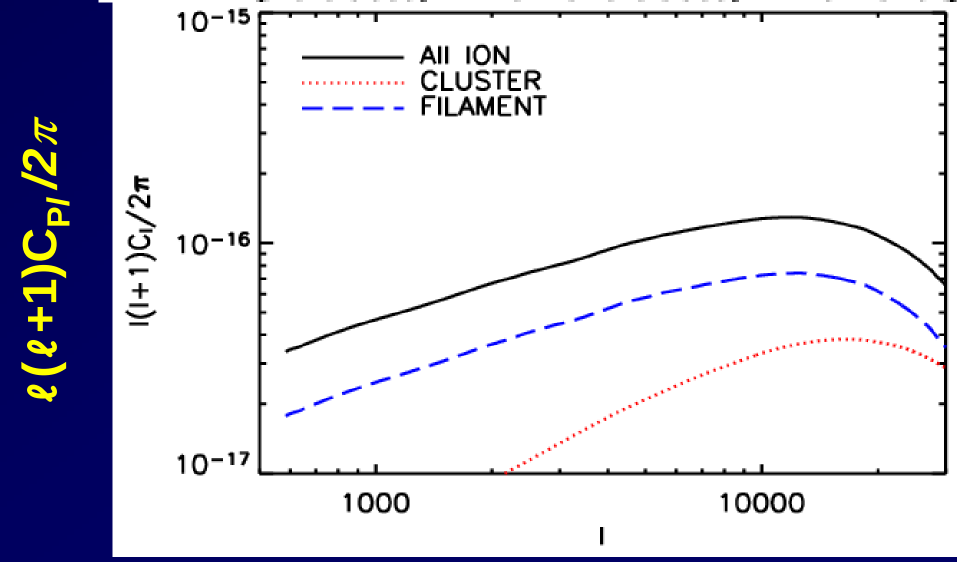
For all ionised particles

Comparing with SZ temperature

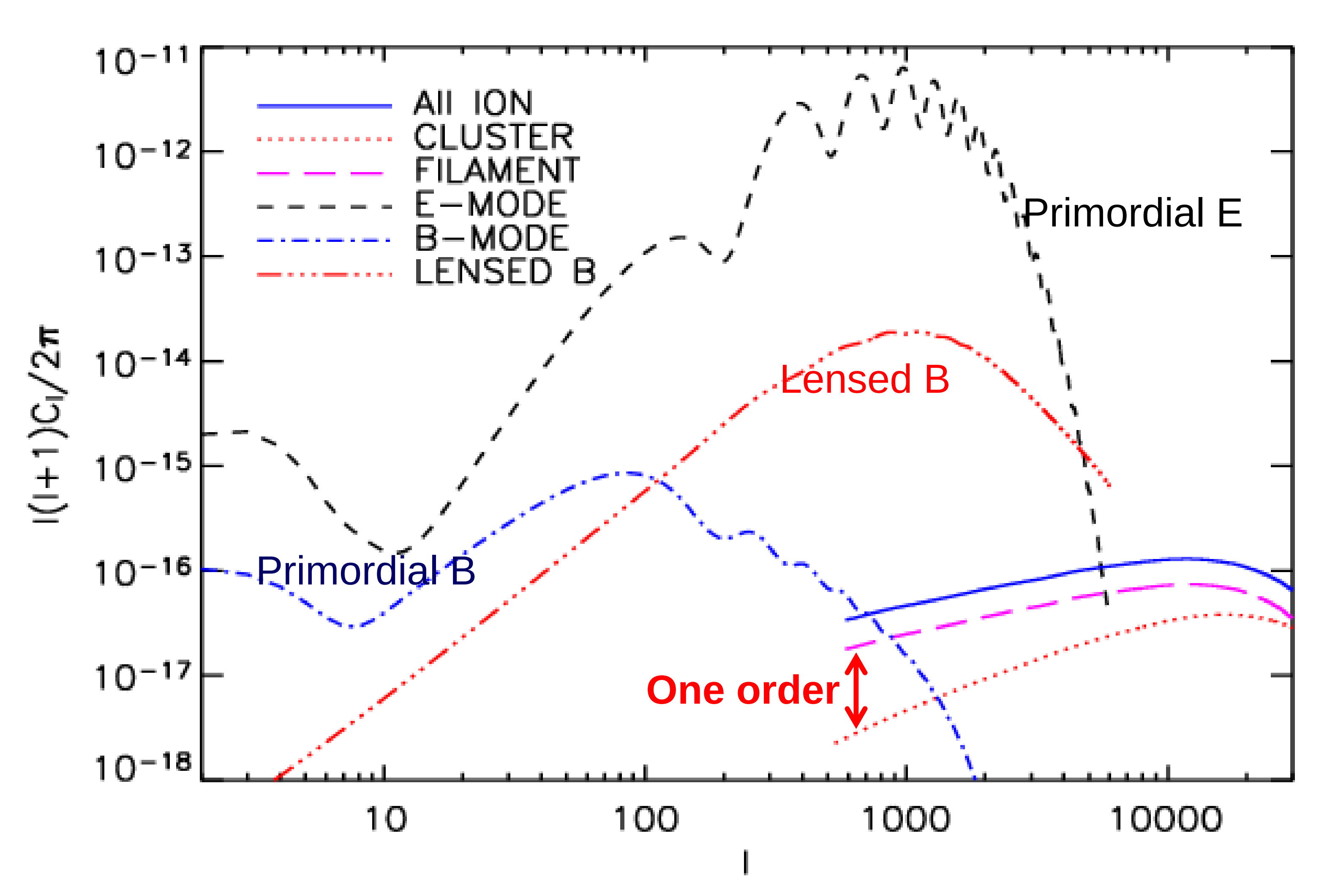
For total ionised particles
5 order of magnitudes



Temp. : Cluster
Polar. : Filament

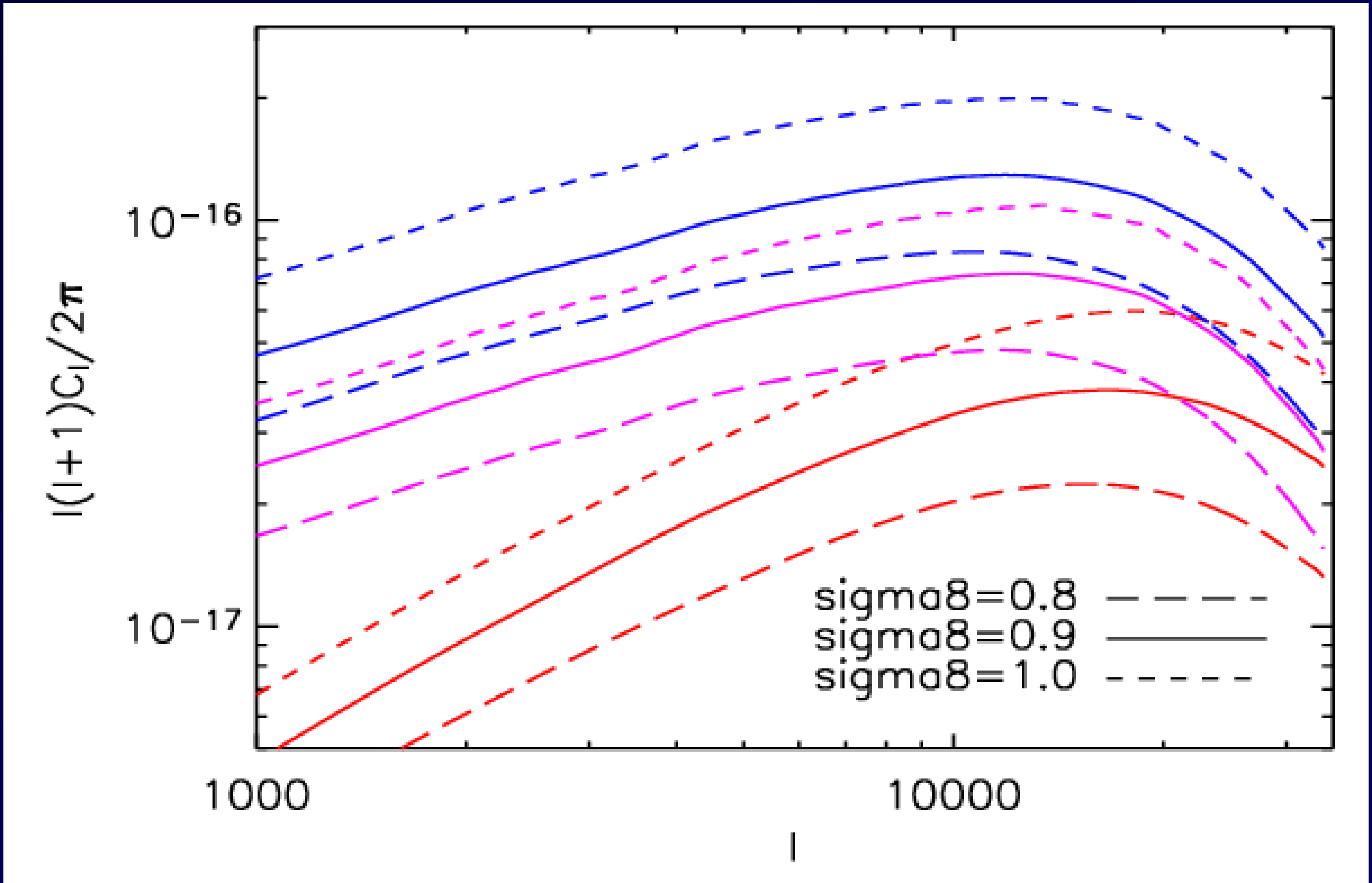


Results


All ION
CLUSTER
FILAMENT
E−MODE
B−MODE
LENSED B
Primordial E
Lensed B
Primordial B
One order
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
$l(l+1)C_l/2\pi$
10
100
1000
10000
l

σ_8

Amplitude $\propto \sigma_8^5$



Summary

1. The E-mode and B-mode have same power because the symmetry of the quadrupole in its k-space is broken by coupling with electron field.
2. The power spectrum $l(l+1)Cl/2\pi$ for all the ionising particles $\sim 10^{-15} \sim 10^{-16}$ K^2
3. Secondary polarisation for cluster and filament dominate at the small scales.

Summary

4. At the intermediate scales, the B-mode power is dominated by the lensing generated power spectrum.
5. The amplitude of the secondary polarisatioin $\propto \sigma_8^5$
6. The power contribute from filament is much larger than the ICM different with the case of tSZ.

Why Filament Dominate?